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ON THE INFLUENCE OF TEMPERATURE UPON THE DEVELOPMENT OF EGGS OF *PAGROSOMUS MAJOR* (TEMMINCK & SCHLEGEL)

By

Eiji Kajiyama.

The present study was done to ascertain the optimum temperature of water for hatching the eggs of *Pagrosomus major* (Temminck and Schlegel). Parent fishes were caught in water near Sisaka Island in Ehime Prefecture on May 25th, 1927, and carried to Ootyô Fish-cultural Station in a fish-well of a boat. Eggs and sperm taken from them were artificially mixed up in water (specific gravity 1.02535 at 15°C) at the temperature of 16.7°C at 3 o'clock p.m. on the same day and 300～500 fertilized eggs were put in each of ten cups. Those ten cups were transferred at 5 o'clock p.m. one by one into ten chambers of a thermostat[1] maintaining a series of ten constant temperaturs between 9.9°C and 25.0°C. The development of eggs was observed at intervals and dead ones were picked out each time. Water in each cup was very cautiously changed with water of the same temperature as that in the cup.

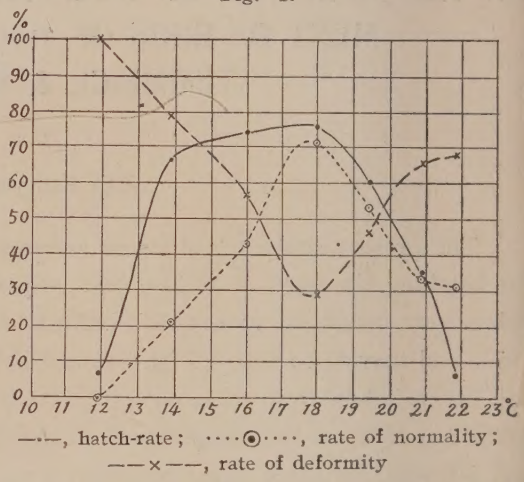
Table I.

	I	II	III	IV	V	VI	VII	VIII	IX	X
Mean temperature of water	25.0	23.3	21.8	20.8	19.4	18.0	16.0	13.9	11.8	9.9
Mean variation of temperature	0.0	0.1	0.1	0.1	0.2	0.1	0.0	0.2	0.1	0.1
Total number of eggs	418	507	400	394	448	451	392	380	286	385
Number of dead eggs	418	507	37	254	178	111	106	128	270	385
Number of hatched larvae	0	0	25	140	270	340	286	252	16	0
Number of normalities	0	0	8	46	128	240	124	52	0	0
Number of deformities	0	0	17	94	142	100	162	200	16	0
Hatch-rate	0.0	0.0	6.3	35.5	60.3	75.6	72.9	66.3	5.6	0.0
Rate of normality	—	—	32.0	32.9	47.4	70.6	43.3	20.6	0.0	—
Rate of deformity	—	—	68.0	67.1	52.6	29.4	56.7	79.4	100.0	—
Mean hatching-hours	—	—	33.0	39.0	43.9	51.7	64.7	84.5	113.6	—
Mean variation of hatching-hours	—	—	2.9	3.1	3.0	2.4	3.3	5.1	—	—

(1) J. Imp. Fish. Inst. XX, 4.

The details of the experiment are given in Table A. Table I gives hatch-rate*, rate of normality†, rate of deformity‡, and hatching-hours§. Fig. 1. shows the relations of hatch-rate and of rates of normality and deformity to temperature of water. From Fig. 1, we know that optimum temperature for hatching the eggs of *Pagrosomus major* is about 17.7°C; because, at this temperature both hatch-rate and rate of normality have maximum values, 76% and 73% resp., and rate of deformity, a minimum, 28%. Notwithstanding hatch-rate is high and rate of deformity is comparatively high at 13°~16°C as seen in Fig. 1. This may be considered to result from the fact that some eggs hatch out deformed at lower temperature, while they are dead at higher one.

Fig. 1.



—·—, hatch-rate; ····⊙····, rate of normality; ——×——, rate of deformity

Table II gives the hatching-hours and hatching-period‖ at several temperatures. The relations of hatching-hours and hatching-period to the temperature

Table II.

Temp. of water °C	21.8	20.8	19.4	18.0	16.0	13.9	11.8
Mean hatching-hours	33.0	39.0	43.9	51.7	64.7	84.5	113.6
Hatching-period	29~37	33~51	37~55	43~57	59~77	73~101	109~119

are shown in Fig. 2. From Table II and Fig. 2, we know that both hatching-hours and hatching-period become shorter as the temperature rises. When we denote either hatching-hours or the beginning or the end of hatching-period by T, and the temperature by θ we get the formula(1):

* Hatch-rate means rate of number of hatched eggs to total number of eggs in each cup.

† Rate of normality means rate of number of normally formed larvae to total number of hatched eggs.

‡ Rate of deformity means rate of number of deformed larvae to total number of hatched eggs.

§ Hatching-hours means number of hours taken for an egg in hatching.

‖ Hatching-period means the duration of time from the time at which the first egg hatches out to the time at which the last one hatches out.

(1) J. Imp. Fish. Inst. XXI. 1.

A. 經過表

m. t. 平均溫度。 m. v. t. 溫度ノ平均差。
no. e. 收容卵數。 d. e. 死卵數。
h. l. 孵化卵數。 def. 畸形數。 nor. 整形數。
T. 經過時間。

A. Details of experiment

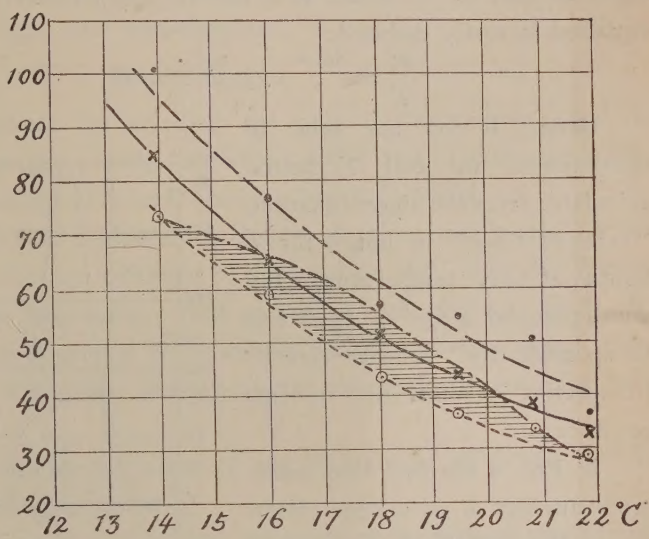
m. t. mean temperature. m. v. t. mean variation of temp.
no. e. number of eggs. d. e. no. of dead eggs.
h. l. no. of hatched larvae. def. no. of deformities.
nor. no. of normalities. T. lapse of time.

			I			II			III			IV			V			VI			VII			VIII			IX			X		
m. t.			25.0			23.3			21.8			20.8			19.4			18.0			16.0			13.9			11.8			9.9		
m. v. t.			0.0			0.1			0.1			0.1			0.2			0.1			0.0			0.2			0.1			0.1		
no. e.			420			507			400			394			448			451			392			382			285			285		
		T.	d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.	
				def.	nor.		def.	nor.		def.	nor.		def.	nor.		def.	nor.		def.	nor.		def.	nor.		def.	nor.		def.	nor.		def.	nor.
25/V	p.m. 6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	5	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
26/V	a.m. 2	9	404	0	0	477	0	0	276	0	0	47	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
	6	13	14	0	0	30	0	0	81	0	0	143	0	0	62	0	0	10	0	0	1	0	0	0	0	0	3	0	0	1	0	0	0
	10	17							9	0	0	13	0	0	44	0	0	41	0	0	38	0	0	18	0	0	1	0	0	12	0	0	0
	p.m. 2	21							3	0	0	7	0	0	9	0	0	29	0	0	16	0	0	12	(	0	2	0	0	1	0	0	0
	6	25							3	0	0	4	0	0	9	0	0	8	0	0	9	0	0	27	0	0	24	0	0	6	0	0	0
	10	29							0	0	3	16	0	0	2	0	0	0	0	0	2	0	0	7	0	0	66	0	0	14	0	0	0
27/V	a.m. 0	31							0	8	4	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	51	0	0	4	0	0	0
	2	33							0	1	0	1	0	10	0	0	0	0	0	0	1	0	0	7	0	0	13	0	0	9	0	0	0
	4	35							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	37							3	8	1	12	49	30	0	3	7	2	0	0	3	0	0	2	0	0	17	0	0	37	0	0	0
	8	39										5	11	2	0	0	12	1	0	0	0	0	0	0	0	0	16	0	0	63	0	0	0
	10	41										0	8	3	2	4	61	0	0	0	0	0	0	18	0	0	21	0	0	107	0	0	0
	p.m 0	43										0	9	0	15	67	41	0	0	1	0	0	0	0	0	0	0	0	0	63	0	0	0
	2	45										2	2	0	0	6	3	0	0	1	0	0	0	1	0	0	4	0	0	1	0	0	0
	4	47										2	7	1	15	21	2	0	0	16	0	0	0	8	0	0	7	0	0	6	0	0	0
	6	49										1	6	0	1	11	1	3	20	80	0	0	0	0	0	0	23	0	0	44	0	0	0
	8	51										1	2	0	7	14	0	2	14	56	0	0	0	0	0	0	0	0	0	1	0	0	0
	10	53													7	7	1	0	29	38	0	0	0	0	0	0	0	0	0	1	0	0	0
28/V	a.m. 0	55													1	9	0	12	33	58	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	57																0	4	0	3	0	0	0	0	0	0	0	0	14	0	0	0
	4	59																			0	21	12	0	0	0	0	0	0				
	6	61																			1	21	30	0	0	0	6	0	0				
	8	63																			2	25	47	1	0	0	0	0	0				
	10	65																			12	14	29	0	0	0	0	0	0				
	p.m. 0	67																			8	27	2	2	0	0	0	0	0				
	2	69																			1	17	3	0	0	0	4	0	0				
	4	71																			0	20	0	0	0	0	1	0	0				
	6	73																			4	6	0	1	2	2	0	0	0				
	8	75																			0	0	0	0	0	0	0	0	0				
29/V	10	77																			5	11	1	0	20	11	0	0	0				
	0	79																						0	0	0	0	0	0				
	2	81																						1	65	33	0	0	0				
	4	83																						3	8	4	0	0	0				
	6	85																						2	4	0	1	0	0				
	8	87																						7	42	1	0	0	0				
	10	89																						3	22	1	1	0	0				
	p.m. 0	91																						3	4	0	0	0	0				
	2	93																						3	5	0	1	0	0				
	4	95																						0	5	0	0	0	0				
	6	97																						1	12	0	1	0	0				
	8	99																						0	6	0	0	0	0				
	10	101																						1	5	0	0	0	0				
30/V	a.m. 2	105																									0	0	0				
	4	107																									0	0	0				
	6	109																									5	4	0				
	8	111																									0	0	0				
	10	113																									0	5	0				
	p.m. 0	115																									0	0	0				
	2	117																									0	0	0				
	4	119																									1	7	0				
	total		420	0	0	507	0	0	375	17	8	254	94	46	178	142	128	111	100	240	106	162	124	130	200	52	269	16	0	385	0	0	

	I	II	III	IV	V

$Te^{-a\theta}=C$ (a and C are some constants), because $\log T$ & θ have a rectilinear relation as shown in Fig. 3. In this case we obtain $a=.115$, $C=417$ for mean hatching-hours, $C=364$ for the beginning of hatching-period, $C=473$ for the end of hatching-period, and the temperature coefficient, $Q_{10}^{\theta}=3.16$.

Fig. 2.



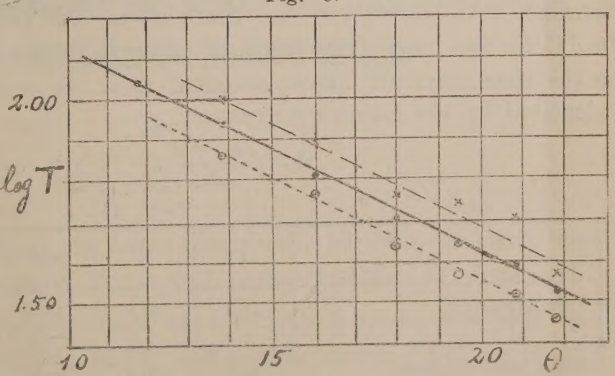
· – – –, end of hatching-period; ⊙····, beginning of hatching-period; × —— mean hatching-hours; ≡ period of time during which the majority of hatched larvae was normal.

Again in Table A we see that normal larvae seem to have hatched at the beginning of hatching-period while deformed ones at the end. So, the rate of normality decreases in the course of hatching-period. Table III gives period of time during which the majority of hatched larvae is normal at different temperatures. From Table III and Fig. 2, we know that the period of time is the longest at the optimum temperature (15 hours at 18 °C) and it becomes shorter as the temperature goes far from the optimum one.

Table III.

Temperature of water °C	23.3	21.8	20.8	19.4	18.0	16.0	13.9	11.8
Period of time during which the majority of hatched larvae is normal	—	25~29	31~33	35~41	41~55	57~65	71~73	—

Fig. 3.



– – × – –, end of hatching-period; ····⊙····, beginning of hatching-period; ——·——, mean hatching-hours; log T, common logarithm of time in hours; θ, temperature °C.

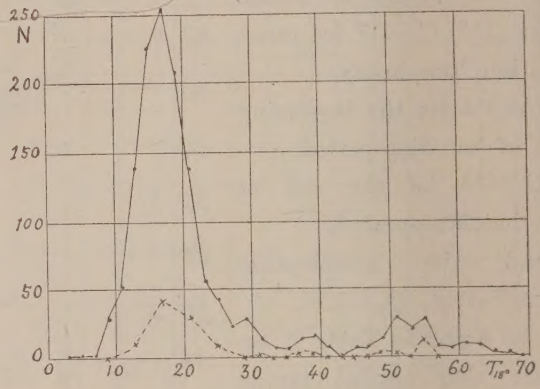
If the state of development of eggs in T hours at any temperature, θ°C, is

equal to that in T_0 hours at a definite temperature, θ_0 °C, then the following equation is easily deduced:

$$\frac{T_0}{T} = e^{\alpha(\theta_0-\theta)} = Q_{10}^{\frac{\theta_0-\theta}{10}}.$$

Hence, if for the sake of convenience, we call T_0 hours, calculated from the above equation, "relative time" in hours for T hours at any temperature, the developmental stage of eggs can be specified by "ralative time", irrespective of difference in temperatnre.

Fig. 4.



N: number of dead eggs; T_{18}°; "relative time" in hours, when θ_0=18°C, —·— : total number of dead eggs arissen in an hour of "relative time" ·· × ··: number of dead eggs an hour when temperature was 18°C

In Fig. 4 the full line represents number of dead eggs arisen in an hour of "relative time" after T_0 hours of "relative time" when θ_0=18°C, and the dotted line, number of dead eggs arisen in an hour after T_0 hours at 18°C. From this figure we know that at this temperature dead eggs arise abundantly at about 17th and 37th hours of "relative time" and also during the hatching-period (about from 45th to 65th hour of "relative time").

The time intervals so far described were all counted from the instant when the eggs were transferred into thermostat. But the eggs were kept in water at 16.7°C for two hours from fertilization until the start of the hatching experiment, so the time intervals above obtained must be corrected by adding Δ hours, calculated by the following equation:

$$\Delta = \frac{16.7 \times 2}{\theta}.$$

Table IV.

	I	II	III	IV	V	VI
Temperature °C	21.8	20.8	19.4	18.0	16.0	13.9
Δ	1.5	1.6	1.7	1.9	2.1	2.4
Mean hatching-hours	34.5	40.6	45.6	53.6	66.8	86.9
Hatching-period	30.5–38.5	34.6–52.6	38.7–56.7	44.9–58.9	61.1–79.1	75.4–103.4
First critical period for eggs	10.5	14.6	14.7	18.9	19.1	27.4

Table IV gives corrected values of mean hatching-hours, hatching-period and the time when dead eggs arise abundantly.

Summary.

1. Optimum temperature for hatching the eggs of *Pagrosomus major* is 17.7°C (in sea water of specific gravity 1.02535 at 15°C) and in this case hatch-rate is 76%, rate of normality 72% and hatching-hours 55 hours.

2. Even at the optimum temperature deformed larvae much arise at the end of hatching-period while at unfavorable temperature still normally formed larvae much arise at the beginning. And period of time during which the majority of hatched larvae is normal is the longest at the optimum temperature (15 hours at 18 °C) and it becomes shorter as the temperature goes far from the optimum.

5. Dead eggs arise abundantly about 19 and 39 hous (at 18°C) after fertilization and throughout hatching-period.

4. The relation between hatching-hours and temperature follows the formula

$$Te^{-a\theta} = C,$$

and in this case we get

$$a = .115\ ;\ C = 417\ ;\ Q_{10} = 3.16.$$

April, 1928.

Ootyô Fish-cultural Station
Imp. Fish. Institute.

ON THE INFLUENCE OF SPECIFIC GRAVITY OF SEA WATER UPON THE DEVELOPMENT OF EGGS OF *PAGROSOMUS MAJOR* (TEMMINCK & SCHLEGEL)

By

Eiji Kajiyama.

Parent fishes were caught in the water near Sisaka Island in Ehime Prefecture on May 26th 1927 and carried to Ootyô Fish-cultural Station in a fish-well of a boat. Artificial fertilization was made at 3 o'clock p.m. on the same day in sea water whose temperature was 16.7°C and specific gravity, 1.02535 at 15°C.[1] At 5 o'clock p.m., 100~200 fertilized eggs were put in each of ten glass cups

(1) All the values of specific gravity in the present paper are those at 15°C

which contained sea water of different specific gravity ranging from 1.02288 to 1.03196. Then the cups were transferred into a thermostat keeping 16.7°C. The eggs sank in sea water of specific gravity below 1.02381 and floated in 1.02567, while they were suspended in 1.02457.

Then the development of eggs were observed at intervals, taking out dead eggs, and changing very cautiously the water with that of the same specific gravity.

The details of the experiment are given in Table B. Table I gives hatch-rate*, rates of normality and deformity**, and hatching-hours†. Fig. 1 shows the relation of hatch-rate etc. to the specific gravity.

Table I.

	I	II	III	IV	V	VI	VII	VIII	IX	X
Specific gravity	1.03196	1.03092	1.02989	1.02912	1.02839	1.02731	1.02567	1.02457	1.02381	1.02288
Number of eggs	158	180	195	186	198	178	205	130	129	126
Number of dead eggs	124	107	119	92	103	76	37	49	120	120
Number of hatched larvae	44	73	76	94	95	102	168	81	9	6
Number of normalities	6	6	12	12	17	48	107	57	4	1
Number of deformities	38	67	64	82	78	54	61	24	5	5
Hatch-rate	26.2	40.6	39.0	50.7	48.0	58.3	82.0	62.3	7.0	4.7
Rate of normality	13.7	8.2	15.8	12.8	17.9	47.0	63.8	70.4	44.4	16.7
Rate of deformity	86.3	91.8	84.2	87.2	82.1	53.0	36.2	29.6	55.6	83.3
Mean hatching-hours	58.7	62.3	60.8	60.0	59.1	57.8	57.9	55.0	59.6	64.3
,, mean difference	4.7	5 3	4.2	4.2	4.1	3.4	2.2	4.6	4.5	3.3

From Fig. 1. we know that the optmum specific gravity for hatching the eggs of *Pagrosomus major* is about 1.02520, because, in sea water of this specific gravity both hatch-rate and rate of normality have muximum values, 83% and 72% resp., while the rate of deformity has a minimum, 28%. From this figure we know that hatch-rate is very low in the sea water of specific gravity below 1.02400, which does not float the eggs, and that above 1.02700 rate of mormality

* Hatch-rate means rate of numbers of hatched eggs to the total number of eggs in each cup.

** Rates of normality and deformity mean respectively the rates of number of normally formed and that of deformed learvae to the total number of hatched eggs.

† Hatching-hours means number of hours taken for an egg in hatching.

B. 經過表

s. g. 比重。　no. e. 收容卵數。
d. e. 死卵數。　h. l. 孵化卵數。
def. 畸形數。　nor. 整形數。

B. Details of experiment

s. g. specific gravity.　no. e. number of eggs.
d. e. no. of dead eggs.　h. l. no. of hatched larvae.
def. no. of deformities.　nor. no. of normalities.

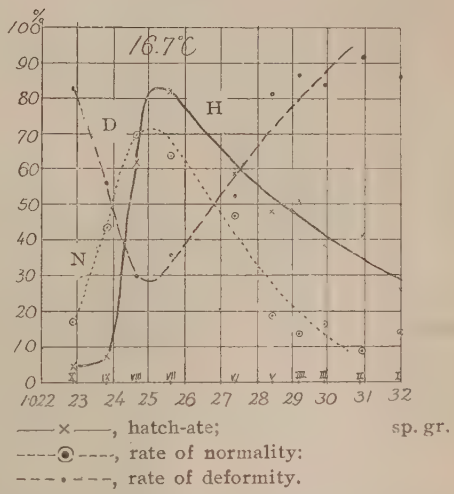
			I			II			III			IV			V			VI			VII			VIII			IX			X		
s. g.			1.03196			1.03092			1.02989			1.02912			1.02839			1.02731			1.02567			1.02457			1.02381			1.02288		
no. e.			168			180			195			186			198			178			205			130			129			126		
		T.	d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.		d.e.	h. l.	
				def.	nor.		def.	nor.		def.	nor.		def.	nor.		def.	nor.		def.	nor.		def.	nor.		def.	nor.		def.	nor.		def.	nor.
26/V	6 p.m.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27/V	2 a.m.	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	13	25	0	0	8	0	0	8	0	0	24	0	0	25	0	0	14	0	0	7	0	0	40	0	0	18	0	0	13	0	0
	10	17	2	0	0	8	0	0	8	0	0	5	0	0	2	0	0	2	0	0	2	0	0	0	0	0	8	0	0	1	0	0
	2 p.m.	21	4	0	0	8	0	0	6	0	0	7	0	0	7	0	0	5	0	0	9	0	0	2	0	0	53	0	0	13	0	0
	6	25	0	0	0	0	0	0	0	0	0	4	0	0	3	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	10	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28/V	2 a.m.	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	37	6	0	0	6	0	0	5	0	0	10	0	0	6	0	0	7	0	0	5	0	0	2	0	0	30	0	0	62	0	0
	10	61	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4	0	0	12	0	0
	2 p.m.	45	2	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0
	4	47	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	49	1	0	0	2	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	2	0	0
	8	51	0	0	1	0	0	1	0	0	1	0	1	2	0	0	2	0	1	3	0	0	5	0	3	33	1	0	1	0	0	0
	10	53	3	2	2	0	1	2	1	0	1	0	0	2	3	3	8	0	1	2	0	3	16	0	1	20	0	0	0	1	0	0
29/V	0 a.m.	55	3	12	2	0	3	0	2	1	6	2	2	3	5	10	3	1	3	13	0	1	3	0	0	2	1	0	2	0	0	0
	2	57	3	8	1	0	4	0	11	18	4	11	34	3	4	26	2	2	11	23	1	18	81	0	0	1	2	1	1	1	1	0
	4	59	0	3	0	14	15	1	1	10	0	4	13	0	5	7	1	0	7	6	7	10	2	0	6	1	0	0	0	0	0	0
	6	61	0	1	0	4	6	2	4	11	0	1	7	1	4	8	1	0	7	1	0	15	0	0	3	0	0	1	0	1	0	0
	8	63	4	3	0	3	3	0	2	6	0	3	5	0	2	8	0	6	8	0	0	1	0	0	2	0	0	0	0	0	1	1
	10	65	19	0	0	6	9	0	5	7	0	1	5	0	3	4	0	4	8	0	0	3	0	0	0	0	0	1	0	0	1	0
	0 p.m.	67	7	2	0	5	5	0	5	0	0	0	3	0	0	4	0	5	6	0	0	0	0	3	2	0	2	0	0	1	0	0
	2	69	22	5	0	8	5	0	6	4	0	0	5	0	2	4	0	1	2	0	0	3	0	2	7	0	0	2	0	0	2	0
	4	71	2	2	0	2	5	0	3	2	0	0	4	0	1	1	0	1	0	0	0	1	0									
	6	73	7	0	0	3	11	0	5	5	0	2	3	0	1	3	0	6	0	0	1	0	0									
	8	75	3	0	0	1	0	0	5	0	0	4	0	0	3	0	0	6	0	0	1	6	0									
	10	77	1	0	0	1	0	0	7	0	0	7	0	0	12	0	0	5	0	0												
30/V	0 a.m.	79	0	0	0	1	0	0	12	0	0	0	0	0	0	0	0	5	0	0												
	2	81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0												
	4	83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0												
	6	85	8	0	0	26	0	0	21	0	0	6	0	0	14	0	0	5	0	0												
	total		124	38	6	107	67	6	119	64	12	92	82	12	103	78	17	76	54	48	37	61	107	49	24	57	120	5	4	120	5	1

is very low though hatch-rate is comparatively high.

Table II gives the hatching-hours and hatching-period* at different specific gravities. The relations of hatching-hours and hatching-period to specific gravity are shown in Fig. 2. From Table II and Fig. 2 we know that both hatching-hours and hatching-period are almost independent of specific gravity.

In table B we see that normal larvae seem to have hatched at the begining of hatching-period while deformed larvae, at the end. So, the rate of production

Fig. 1.



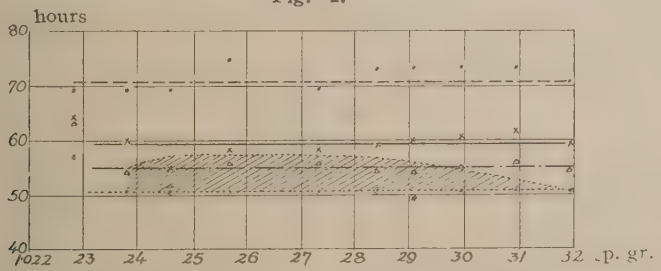
——×——, hatch-ate;
----⊙----, rate of normality:
---•---, rate of deformity.

Table II

	I	II	III	IV	V	VI	VII	VIII	IX	X
Specific gravity	1.03196	1.03092	1.02989	1.02912	1.02839	1.02731	1.02567	1.02457	1.02381	1.02288
Mean hatching-hours	58.7	62.3	60.8	60.0	59.1	57.8	57.9	55.0	59.6	64.3
Hatching-period	51-71	51-73	51-73	49-73	51-73	51-69	51-75	51-69	51-69	57-69
Mean hatching-hours of normal larvae	54.0	56.3	55.2	54.4	54.3	56.2	55.9	52.0	54.5	63.0
Hatching-period of normal larvae	51-57	51-61	51-57	49-61	51-61	51-61	51-59	51-59	51-57	—

Time given in this table are reckoned from the instant at which eggs were put in thermostat.

Fig. 2.



× —— mean hatching-hours; ⊙------ beginning of hatching-period;
• — — end of hatching-period; △— - — mean hatching-hours of normal larvae;
//////////// period of time during which the majority of hatched larvae is normal.

* Hatching-poriod means the duration of time from the time at which the first egg hatches out to the time at which the last one hatches out.

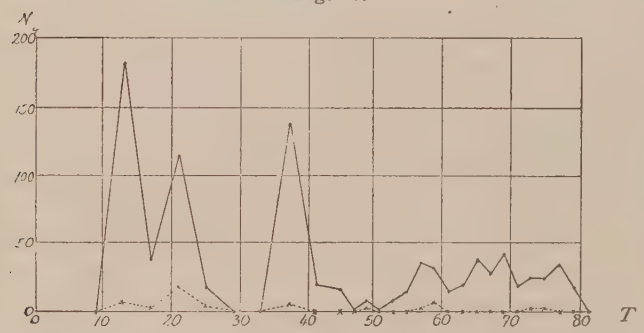
of normal larvae decreases in the course of hatching-period. Table III gives the period of time during which the majority of hatched larvae was normal. In Fig. 2, the shaded range shows the period just referred to. From Table III and Fig. 2, we know that we have the longest period for the production of mostly normal larvae at the optimum specific gravity (8 hours at 1.02520).

Table III

	I	II	III	IV	V	VI	VII	VIII	IX	X
Specific gravity	1.02788	1.02381	1.02457	1.02567	1.02731	1.02839	1.02912	1.02989	1.03092	1.03196
Period of time during which the majority of hatched larvae is normal	—	49–57	49–57	49–57	49–57	49–53	47–55	49–55	49–53	49–53

Time given in this table is reckoned from the instant at which eggs were put in thermostat.

Fig. 3.



N: number of dead eggs an hour; ——— in total; ----×---- at 1.02567. T; time in hours

The rate of development of eggs is not affected by specific gravity of sea water, as already remarked. Fig. 3 represents the number of dead eggs at 1.02567 an hour and the total number of dead eggs an hour. We may say from Fig. 3 that the critical periods for the eggs are about 19 and 39 hours after fertilization and also during hatching-period. This result coincides which that obtained in the temperature experiment reported in another paper.

Summary

1. Optimum specific gravity for hatching the eggs of *Pagrosomus major* is 1.02520 (sp. gr. at 15°C) at 16.7°C in this case the hatch-rate is 83% and the rate of normality 72%.

2. Normal larvae seem to hatch at the beginning of hatching-period while deformed ones at the end of that period. The period of time during which the majority of hatched larvae is normal, has a maximum value at the optimum supecific gravity (8 hours at 1.02520), and that period becomes shorter as specific

gravity goes far from the optimum value.

3. We have critical periods for the eggs about 19 and 39 hours after fertilization and also throughout the hatching-period.

April, 1928

Ootyô Fish-cultural Station,
Imp. Fish. Institute.

ON THE INFLUENCE OF THE TEMPERATURE AND SPECIFIC GRAVITY OF SEA WATER UPON THE DEVELOPMENT OF LARVAE OF *PAGROSOMUS MAJOR* (TEMMINCK & SCHLEGEL)

By

Eiji Kajiyama.

The present study was done to know the optimum temperature and the optimum specific gravity of sea water for the development of larvae of *Pagrosomus major*.

1) The influence of temperature.

Parent fishes were caught on June 7th 1927. Artificial fertilization was performed at 3 o'clock p.m. Fertized eggs were kept in a large glass vessel put on a table. 30～40 larvae hatched at noon on 9th were put in each of ten cups containing 100 c.c. of water of specific gravity 1.02490 (15°C). These cups were immediately transferred one by one into ten chambers of a thermostat[1] maintaining a series of ten constant temperatures between 9.4°C and 24.6°C.

Table I.

	I	II	III	IV	V	VI	VII	VIII	IX	X
Mean temperature.	24.6	23.1	22.5	20.8	19.7	17.6	16.1	13.4	12.3	9.4
Mean variation of temperature.	0.5	0.5	0.4	0.4	0.4	0.3	0.2	0.3	0.3	0.2
Total numbers of larvae.	36	33	41	33	25	24	31	40	33	34
Death-rate in A stage.	0.0	0.0	0.0	3.0	4.0	12.5	6.5	12.5	12.1	100.0
〃 in B stage.	47.2	15.2	24.4	0.0	12.0	4.2	6.5	82.5	81.8	—
Time taken for the development of A stage only, T_a	30	30	30	36	42	42	54	90	90	
Time taken for the development of A and B stages, T_b	36	42	42	48	54	60	78	138	174	
log T_a	1.48	1.48	1.48	1.56	1.62	1.62	1.73	1.95	1.95	
log T_b	1.56	1.62	1.62	1.68	1.73	1.78	1.89	2.14	2.24	

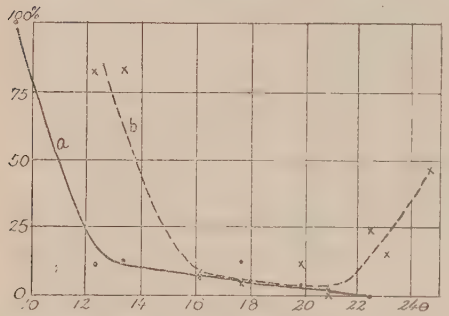
(1) J. Imp. Fish. Inst. XX. 4.

Then the development of larvae was observed at intervals, taking out dead larvae and changing water with that of the same temperature as that in the cup.

The details of the experiment are given in Table C. For the brevity's sake, we shall call the larval stage holding yolk sack the A stage, and the larval stage having yolk sack absorbed but eyes not yet completed, the B stage. Table I gives the death-rate* in A and B stages, and mean value of time during which larvae passed through each stage.

Fig. 1 shows the relation of death-rate in A and B stages to temperature of water. From Fig. 1 we know that the optimum temperature for the development of larvae of *Pagrosomus major* is about from 16°C to 22 °C, because at these temperatures death-rates in A and B stages are minimum, (under 10%).

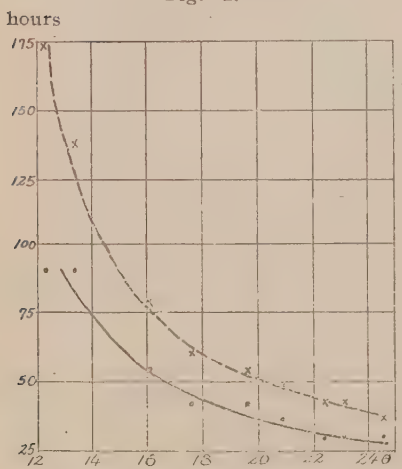
Fig. 1.



a —— Death-rate in A stage; *b* – – – Death-rate in B stage θ : temperature of water.

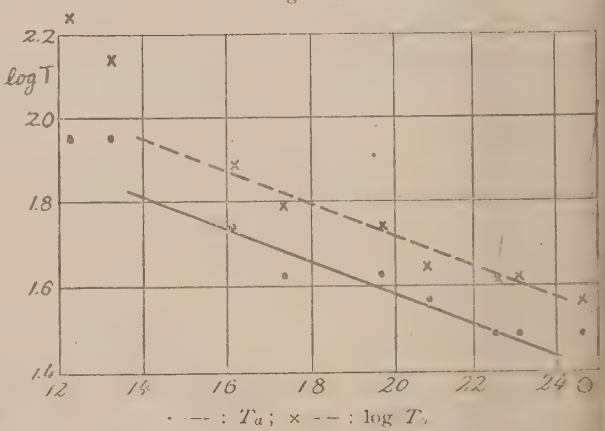
Fig. 2 shows the mean value of time in hours during which larvae passed through A stage and A and B stages. From Fig. 2 we know that the time becomes shorter as the temperature rises.

Fig. 2.



Time taken for the development of A stage, T_a, and A and B stages, T_b θ : temperature of water.

Fig. 3.



· — · : T_a ; × – – : log T_b

Fig. 3 shows the logarithm of the mean number of hours related to temperature. From Fig. 3 we know that the re-

* Death-rate means rate of number of dead larvae to the total number of larvae in each cup.

C. 經 過 表

m. t. 平均溫度。　m. v. t. 溫度ノ平均差。
no. l. 收容らーばノ數。　no. d. 死亡らーばノ數。
d. l. らーば發育狀態。　T. 經過時間。
× らーばノ運動活發ナルモノ。

C. Details of experiment

m. t. mean temperature.　m. v. t. mean variation of temp.
no. l. no. of larvae.　no. d. no. of dead larvae.
d. l. stage of larvae.　T. lapse of time.
× larvae vigorous at stage a.

			I		II		III		IV		V		VI		VII		VIII		IX		X	
m. t.			24.6		23.1		22.5		20.8		19.7		17.6		16.1		13.4		12.3		9.4	
m. v. t.			0.5		0.5		0.4		0.4		0.4		0.3		0.2		0.3		0.3		0.2	
no. l.			36		33		41		33		25		24		31		40		33		34	
Day	hour.	T.	no. d.	d. l.	no. d.	d. l.	no. d.	d. l.	no. d.	d. l.	no. d.	d. l.	no. d.	d. l.	no. d.	d. l.	no. d.	d. l.	no. d.	d. l.	no. d.	d. l.
9/VI	2 p.m.	0	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a
	8	6	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a
10/VI	2 a.m.	12	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a
	8	18	0	a	0	a	0	×a	0	×a	0	×a	0	×a	0	a	0	a	0	a	0	a
	2 p.m.	24	0	a	0	a	0	×a	0	×a	0	×a	0	×a	0	×a	0	×a	0	a	0	a
	8	30	0	×a	0	×a	0	×a	0	×a	0	×a	0	×a	0	×a	0	×a	0	a	0	a
11/VI	2 a.m.	36	17	b	5	b	10	b	1	×a	0	×a	3	×a	1	×a	2	×a	1	×a	2	a
	8	42	1	c	0	b	0	b	0	b	1	×a	0	×a	0	×a	0	×a	0	×a	1	a
	2 p.m.	48	1	c	1	c	0	c	0	b	0	b	0	b	0	×a	0	×a	1	×a	0	a
	8	54	0	c	3	c	0	c	0	c	3	b	0	b	1	×a	0	×a	0	×a	0	a
12/VI	2 a.m.	60	0	c	1	c	1	c	1	c	0	c	1	b	0	b	0	a×	0	×a	2	a
	2 p.m.	72	4	c	1	c	1	c	5	c	0	c	3	c	1	b	0	×a	0	×a	17	a
	8	78	0	c	0	c	1	c	4	c	0	c	0	c	1	b	0	×a	0	×a	12	a
13/VI	2 a.m.	84	0	c	0	c	0	c	1	c	0	c	0	c	0	c	2	×a	2	×a		
	8	90	0	c	1	c	0	c	1	c	0	c	0	c	3	c	1	×a	0	×a		
	8 p.m.	102	0	c	0	c	0	c	0	c	10	c	11	c	0	c	4	b	1	b		
14/VI	8 a.m.	114	0	c	1	c	0	c	0	c	1	c	3	c	7	c	0	b	5	b		
	8 p.m.	126	0	c	0	c	0	c	0	c	1	c	1	c	2	c	21	b	16	b		
15/VI	8 a.m.	138	3	c	0	c	0	c	0	c	0	c	0	c	9	c	8	b	0	b		
	8 p.m.	150	8	c	2	c	1	c	0	c	0	c	0	c	2	c	1	c	0	b		
16/VI	8 a.m.	162	1	c	7	c	9	c	0	c	0	c	0	c	1	c	1	c	5	b		
	8 p.m.	174	1	c	6	c	12	c	1	c	1	c	2	c	0	c			0	b		
17/VI	8 a.m.	186			5	c	6	c	12	c	0	c			1	c			2	c		
	8 p.m.	198							4	c	7	c			1	c						
18/VI	8 a.m.	210							2	c	1	c			1	c						
	8 p.m.	222							1	c												

D. 經 過 表

s. g. 比重

D. Details of experiment

s. g. specific gravity.

			I		II		III		IV		V		VI	
s. g.			1.02100		1.02200		1.02300		1.02410		1.02510		1.02610	
no. l.			21		21		18		20		18		22	
Day	hour	time	no. d.	d. l.	no. d.	d. l.	no. d.	d. l.	no. d.	d. l.	no. d.	d. l.	no. d.	d. l.
10/VI	8 p.m.	8	0	a	0	a	0	a	0	a	0	a	0	a
11/VI	8 a.m.	20	0	a	0	a	0	a	0	a	0	a	0	a
	2 p.m.	26	1	a	0	a	0	a	0	a	0	a	0	a
	8 p.m.	32	0	a	0	a	0	a	0	b	0	b	0	b
12/VI	2 a.m.	38	17	b	0	b	0	b	0	b	0	b	0	b
	3 p.m.	51	0	c	0	c	0	c	0	c	2	c	6	c
	8	56	0	c	0	c	0	c	1	c	0	c	1	c
13/VI	2 a.m.	62	0	c	1	c	4	c	0	c	0	c	0	c
	8	68	0	c	0	c	0	c	1	c	2	c	3	c
	8 p.m.	80	2	c	3	c	0	c	1	c	0	c	3	c
14/VI	8 a.m.	92	0	c	1	c	0	c	0	c	0	c	0	c
	8 p.m.	104	0	c	0	c	1	c	0	c	1	c	0	c
15/VI	8 a.m.	116	0	c	1	c	0	c	1	c	1	c	1	c
	8 p.m.	128	0	c	1	c	1	c	2	c	3	c	0	c
16/VI	8 a.m.	140	1	c	1	c	1	c	4	c	3	c	4	c
	8 p.m.	152			4	c	0	c	8	c	1	c	1	c
17/VI	8 a.m.	164			6	c	9	c	2	c	1	c	2	c
	8 p.m.	176			3	c	2	c			4	c	1	c

ion of between mean number of hours, T, and the temperature, θ, follows the rmula

$$Te^{-\alpha\theta} = \text{const.},$$

the optimum range of temperature. And the temperature coefficient, Q_{10}, is this case 2.5.

2) The influence of specific gravity.

Parent fishes were caught on June 6th 1927. Artificial fertilization was formed at 3 o'clock p.m. on the same day. 20 larvae hatched at noon on the 1 were put in each of ten cups containing 100 c.c. of water of different specific avities ranging from 1.0210 to 1.0260.[1] Throughout the experiment these cups ere kept at 19.7°C.

Then, the development of larvae was observed at intervals taking out dead rvae, and changing water in each cup with water of the same specific gravity ; that in the cup.

Table II

	I	II	III	IV	V	VI
Specific gravity	1.02100	1.02200	1.02300	1.02410	1.02510	1.02610
Total number of larvae	21	21	18	20	18	22
Death-rate in A stage	4.8	0.0	0.0	0.0	0.0	0.0
〃 in B stage	80.9	0.0	0.0	0.0	0.0	0.0
Duration of time from hatching out to the end of A stage	32	32	32	26	26	26
Duration of time from hatching out to the end of B stage	38	38	38	38	38	38

The details of the experiment are given in Table D. Table II gives the eath-rate in A and B stages as well as mean numbers of hours taken for the evelopment of A stage and B stages. From Table II we know that the rate development of larvae is independent of specific gravity of sea water and that a water of specific gravity ranging from 1.0220 to 1.0261 is favourable for velopment of the larvae.

Summary.

1) The rate of development of the larvae of *Pagrosomus major* varies in a ect relation to the temperature consistently with van't Hoff's Rule and =2.5.

2) The optimum temperature for development of the larvae is 16~22°C.

1) All the values of specific gravity given hereafter are those at 15°C.

II. 1) The rate of development is independent of specific gravity of sea water.

2) Specific gravity ranging from 1.02200 to 1.02610 is favourable for development of the larvae.

Oôtyo Fish-cultural Station,
Imp. Fish. Institute.

ON THE INFLUENCE OF THE DURATION OF TIME OF VIBRATION UPON THE DEVELOPMENT OF FISH-EGGS.

By

Kyuzo Hata.

In a previous paper,[1] I reported on the influence of vibration upon the eggs of *Oncorhynchus masou* Brevoort at several stages of development.

In the present paper, I shall give an account of the experiment on the influence of the duration of time of vibration upon the eggs of *Oncorhynchus masou* Brevoort and *Salmo irideus* (Gibbons).

Parent fishes of *Oncorhynchus masou* were caught in Lake Kizaki and those of *Salmo irideus*, in a pond at Kizaki Fish-cultural Station Imp. Fish. Inst. The ripe eggs and sperm taken from them were artificially mixed up by the dry method. Firstly, about 100 eggs at a certain stage of development were carefully scattered over wet mosses in a cup and put in the compartment A_1 of a vibration-apparatus,[2] being subject to vibration during various intervals. Then the eggs were transferred to a hatching apparatus which was supplied with running water at 10.9°~11.3°C.

Table I.

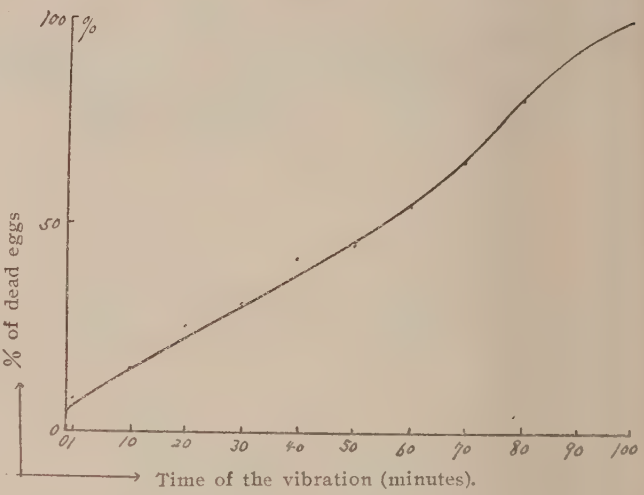
Time of vibration (minutes).		0	1	10	20	30	40	50	60	70	80	90	100
Number of rotation per minute.			56	59	58	55	54	56	56	56	55	56	56
Vibration	Number of eggs tested.	591	57	67	82	70	75	43	80	85	80	99	80
	Number of dead eggs.	25	6	10	21	22	32	20	44	56	68	92	80
	% of dead eggs.	4.2	8.7	14.9	25.6	31.4	42.6	46.5	55.0	65.8	81.2	93.7	100.0
	Number of deformities.	15	1	0	0	0	3	0	0	0	0	0	
	Number of uncom. hatched.	6	0	0	0	0	0	1	1	0	1	0	
	Number of uncom. development.	3	0	2	1	1	0	1	1	0	0	0	

(1). (2) Jour. Imp. Fish. Inst. Vol. XIII, No. 3, 1927.

The developmental stages of these eggs were observed day by day.

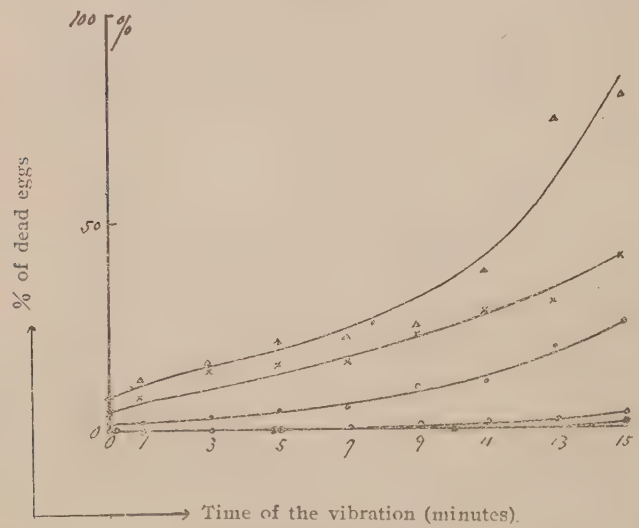
The influence of the duration of time of vibration upon the eggs of *Salmo irideus* is given in Table I. Fig. 1 shows graphically the relation between the duration of time and the death-rate of eggs.

Fig. 1.



The influence of vibration upon the eggs of *Oncorhynchus masou* is given in Table II. Fig. 2 shows the relation between the duration of time and the death-rate.

Fig. 2.



△ 16 days after the fertilization.
× 5 days after the fertilization.
● soon after the fertilization.
○ 31 days after the fertilization.
✻ 42 days after the fertilization.

From Fig. 2 we know that the death-rate of the eggs increases as the duration of time of vibration increases irrespective of the time at which the eggs were influenced by the vibration.

Fig. 3 shows the relation between the death-rate and the time at which the eggs were influenced by the vibration.

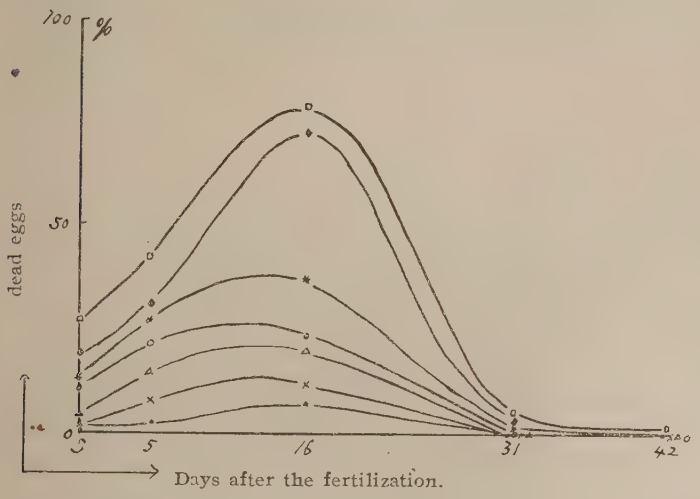
Looking at Fig. 3, we know that the relation between the death-rate and the time coin-

第 二 表 Table II.

振動ヲ與ヘシ階級 Stages.	振動繼續時間（分） Time of vibration. (minute)	0	1	3	5	7	9	11	13	15
受精直後 Soon after fertilization.	一分時ニ於ケル回轉數 Number of rotation per minute.		55	55	55	55	55	55	55	55
	收容卵數 Number of eggs tested.	382	49	46	47	50	49	49	49	48
	總死卵數 Number of dead eggs.	3	1	1	2	3	5	6	9	13
	總死卵率 % % of dead eggs.	0.7	2.0	2.1	4.2	6.0	10.2	12.2	19.3	27.0
	畸形兒數 Number of deformities.	1	0	0	0	0	1	0	0	0
	不完全孵化數 Number of uncom. hatched.	1	0	0	0	0	0	0	0	0
受精後五日目 5 days after fertilization.	一分時ニ於ケル回轉數 Number of rotation per minute.		56	55	55	55	55	55	55	55
	收容卵數 Number of eggs tested.	749	94	96	94	95	99	96	94	96
	總死卵數 Number of dead eggs.	18	8	13	14	15	22	27	29	40
	總死卵率 % of dead eggs.	2.4	8.5	13.5	14.8	15.7	22.2	28.1	30.8	41.6
	畸形兒數 Number of deformities.	1	0	0	0	0	0	0	0	0
	不完全孵化數 Number of uncom. hatched.	5	0	0	0	0	0	1	0	1
受精後十六日目 16 days after fertilization.	一分時ニ於ケル回轉數 Number of rotation per minute.		55	54	55	55	55	54	55	55
	收容卵數 Number of eggs tested.	751	99	96	95	98	89	99	96	98
	總死卵數 Number of dead eggs.	55	12	14	19	20	21	37	71	78
	總死卵率 % of dead eggs.	7.3	12.1	14.5	20.0	20.4	23.5	37.3	73.9	79.5
	畸形兒數 Number of deformities.	1	0	0	0	0	0	0	1	0
	不完全孵化數 Number of uncom. hatched.	1	0	0	0	0	0	1	0	0
受精後三十一日目 31 days after fertilization.	一分時ニ於ケル回轉數 Number of rotation per minute.		56	55	55	55	55	56	56	55
	收容卵數 Number of eggs tested.	776	99	92	94	97	95	94	99	97
	總死卵數 Number of dead eggs.	0	0	0	0	0	1	1	2	3
	總死卵率 % of dead eggs.	0	0	0	0	0	1.0	1.0	2.0	3.0
	畸形兒數 Number of deformities.	0	0	0	0	0	0	0	0	0
	不完全孵化數 Number of uncom. hatched.	0	0	0	0	0	0	0	1	0

振動ヲ與ヘシ階級 Stages.	振動ノ繼續時間（分） Time of vibration. (minute)	0	1	5	10	15	20	25	30	60
受精後四十二日目 42 days after fertilization.	一分時ニ於ケル回數 Number of rotation per minute.		56	56	55	55	55	56	56	56
	收容卵數 Number of eggs tested.	769	88	94	99	99	100	96	98	97
	總死卵數 Number of dead eggs.	0	0	0	0	1	1	1	2	3
	總死卵率 % % of dead eggs.	0	0	0	0	1.0	1.0	1.0	2.0	3.0
	畸形兒數 Number of deformities.	0	0	0	0	0	0	0	0	0
	不完全孵化數 Number of uncom. hatched.	0	1	0	0	0	0	0	0	1

Fig. 3.



● 0 minutes. × 1 minutes. △ 5 minutes. ○ 9 minutes.
✳ 11 minutes ♦ 13 minutes □ 15 minutes S soon after the fertilization.

cides with the result which the author previously got with the eggs of *Oncorhynchus masou*; namely in spite of the duration of time of vibration the injurious influence of the vibration is most conspicuous during 10 to 20 days after fertilization and it is insignificant on and after 25th day after fertilization.

Before closing, I wish to express my best thanks to Dr. M. Tauti for his helpful advice.

Summary

When the eggs of *Oncorhychus masou* and *Salmo irideus* were subjected to the vibration at several stages of developments :—

1. The death-rate of eggs increased with the increase in time of the vibration irrespective of developmental stage.

2. The highest value of the death-rate of the eggs due to the vibration was found in those which were 16 days old after fertilization.

June, 1928.

Kizaki Fish-cultural Station,
Imp. Fish. Inst.

NOTE ON LEADING THE MOVEMENT OF FISH-GROUPS BY ELECTRIC CURRENT

By

Mituyo Okada.

Regarding the possibility of stopping fish-groups by supplying electric current in water, M. Tauti and K. Sugii[1] were successful in their experiment in 1922. The aim of the present study is chiefly to know whether it is also possible or not to lead fish-groups going up a stream into a side-course such as the opening of fish-way at a power station. Although the results of the experiment do not highly promise the possibility in question, some interesting behaviors of fish-groups in response to electric current may be mentioned therefrom.

§ 1. The following three model-streams, each having a branch-stream on one side, were utilized in the experiment.

A: a wooden conduit, 24.5 cm broad and 4 m long, with a branch 6 cm broad, set at ∠R to the main conduit; velocity of water: $s \fallingdotseq 12$ cm/sec; depth of water: $d \fallingdotseq 6$ cm; temperature of water: $\theta \fallingdotseq 12°C$.

B: a long concrete pond, 1.12 m broad and 36.4 m long, with a longitudinal opening 18 cm broad on one side; $s \fallingdotseq 1$ m/min; $d \fallingdotseq 20\sim30$ cm; $\theta \fallingdotseq 13°C$.

C: a large rectangular pond, 3.6 m broad and 34 m long, with a side water-way 82 cm broad, set at ∠R to the longer side of the pond; $s=2$ m/min; $p \fallingdotseq 20$ cm; $\theta \fallingdotseq 18°C$.

The groups of fishes used were those of *Salmo irideus* Gibbons —— smaller ones were put in the model-stream A, and bigger in B —— and those of *Leusiscus hakuensis* Günther, in B and C. Of these fishes the size of body and average sensitivity to the alternating current of 50 cycles, which were employed in the experiment, were as shown in Tab. I.

Three kinds of systems, as shown in Fig. 1, I, II and III, were adopted

Table I.

l: length of fish-body (in cm): v_1: mean of sufficient potential-drop per 1 cm (in volts/cm) to which the fishes were sensible; v_2: mean of sufficient potential-drop per 1 cm (in volts/cm) at which the fishes were found dead. (conductivity of water $=5.6\times10^{-5}$cm ohm^{-1}).

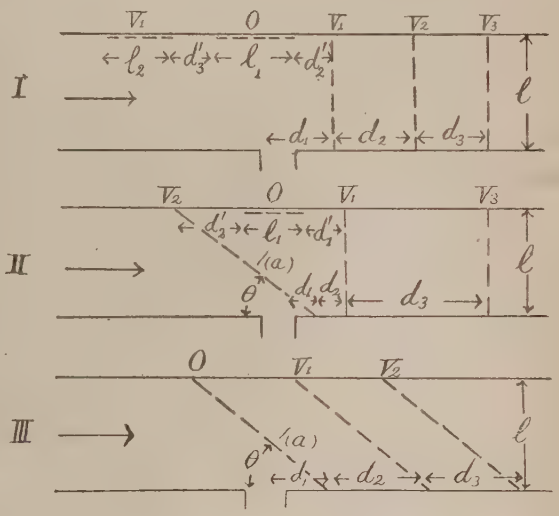
Fishes	l	v_1	v_2
Salmo irideus (smaller)	2.5~3.0	0.104	1.12
Salmo irideus (bigger)	7.5~17	0.026	0.59
Leusiscus hakuensis	10~17	0.039	0.27

(1) T. Ohta: Investigations on electric current and living fish, (in Japanese). Suisan Kenkiushi. Vol. 19, No. 12. p. 432. (1924).

in arrangement of electrodes, a set of plane rectangular nets of metal wires each supported vertically in water. Meshes of the nets were 1.0 cm in A and 15 cm in B and C, except the nets which, having had meshes of 10 cm, crossed the stream (in B) diagonally in the systems of the 2nd and 3rd kinds.

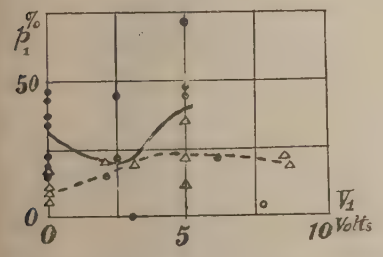
When a group of fishes, running up the stream, meets with a system of electrodes, a part of it, either small or large, turns into the side-course (1), while fishes of the other part either venture to pass through the meshes of nets (1′), or break through the whole system (2). A few among the subdivision (1′), in some occasions, become dead (3), whereas the rest turn back and go down the stream (4). The percentages of such fishes in the total number, were derived from the records of observation with each system of electrodes in both cases where the current was supplied and not. The results are given in Tab. II. Fig. 2 shows the relation between the rate of turning into the side-course, p_1, and the *front*-voltage, V_1 in Fig. 1, I.

Fig. 1.



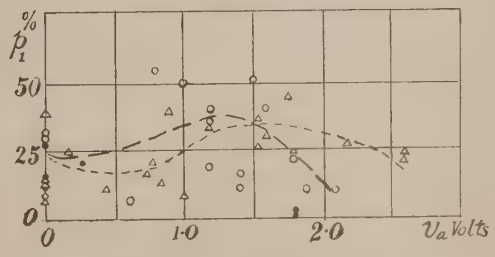
Showing 3 different kinds of arrangement of electrodes represented by broken lines. V_1, V_2, etc.: Voltages relative to that denoted by O; →. direction of fish-groups going up the the stream.

Fig. 2.



Rate of turning into the side-course in systems of the first kind, I.
● —— *Leusiscus hakuensis*;
○ *Salmo irideus* (bigger);
△ ····· *Salmo irideus* (smaller).

Fig. 3.

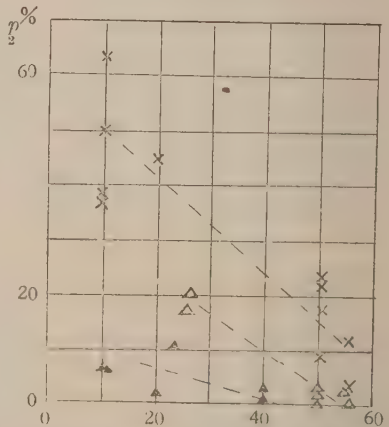


Rate of turning into the side-course in systems of the second and third kind, II and III.
● *Leusiscus hakuensis*; ○ –– *Salmo irideus* (bigger); △ ····· *Salmo irideus* (smaller)

in various systems belonging to the 1st kind ; and Fig. 3, the relation between p_1 and the potential-drop (per 5 cm in A and per 20 cm in B, *i.e.* v_a in Tab. II) at the position denoted by (*a*) in Fig. 1, II and III. Both of these two graphs show that there exists an optimum voltage to make fish-groups turn into the side-course. As v_a assumes the value 5 v_1 or 20 v_a (*i.e.* 0.52 for either the smaller, in A, or the bigger, in B, *Salmo irideus* and 0.78 for *Leusiscus hakuensis*, in B, as seen from Tab. I) to make the majority of fishes feel the current at (*a*)-part, we can say that the optimum voltage is such as to make the potential-drop per unit length at (a)-part about twice as great as what is sufficient to be felt by the majority of fishes.[1]

It was pointed out by Dr. M. Tauti that to stop fish-groups by electric current too high voltage will only result in killing fishes, and it is rather preferable to arrange many electrodes, keeping lower voltages, over wider ranges along the stream, so that the fishes may meet the current of gradually increasing intensity as they further continue their course. The result in Tab. II is in perfect accordance with the rule. In Tab. II, we have the values of $max.\frac{\Delta V}{d}$, which stands for the greatest value of the quotient, $|V_j - V_i|/d_j$, of the voltage between any two electrodes standing across the stream divided by the distance between them. The total extension, $\sum d_j$, of the system of electrodes along the stream is also given in Tab. II. Fig. 4 shows how the rate of breaking through the electrodes, p_2, diminishes as $\sum d_j$ increases, even when the value of $max.\frac{\Delta V}{d}$ is not sufficiently great to stop fishes unless $\sum d_j$ is very great. Again it is seen from Tab. II, that p_2 becomes almost zero when the value of $max.\frac{\Delta V}{d}$ becomes nearly equal to v_2, given in Tab. I, while in the case of *Salmo irideus*, dead fishes are found when the value of $max.\frac{\Delta V}{d}$ becomes as high

Fig. 4.



Rate of breaking through the electrodes, showing to decrease as $\sum d_j$ increases. Data are picked out from Tab. II : △ from I. No. 10~16; ▲ from II. No. 19~24; and × from III. No. 1~3 and 6~13, where $max.\frac{\Delta V}{d}$ are almost the same. *Salmo irideus* (smaller).

(1) In an experiment, the details of which is not here exhibited, it was known that the potential-drop must be less than v_1 in front of the diagonal nets. (See Japanese issue of this Journal).

as about 0.6 v_2.

§ 2. Having taken advantage of the the circumstances that *Leusiscus* were in the spawning-season, the writer undertook another experiment to ascertain whether the action of electric current on parent fishes has any influence upon the hatch-rate of the eggs or on the rate of abnormity of the hatched fry.

Pairs in a group of parent fishes were put in alternating currents of 50 cycles of various intensities for 30 minutes; pairs in another group were put in a considerably strong current of a definite intensity for various hours. Eggs and sperm were taken from those parent fishes just after the stop of electric action; artificial fertilization was performed and the eggs were put in glasses kept in an incubator. The stages of development thereafter were observed at intervals, and the number of hatched eggs and that of abnormal fry whose growth was suspended or which grew in deformed form were reckoned. The result is given in Tab. III, wherefrom we can not find out any bad influences as concerned above.

Table III.—*Leusiscus hakuensis* Günther.

a. Parent fishes were put in currents for 30 minutes.

Intensity of current: potential-drop per 1cm	Number of eggs	No. of hatched eggs	Hatch-rate	Number of fry	No. of ab-normal fry	Rate of abnormity
0 volts	485	438	90.4%	427	39	9.2%
0.0084	298	289	97.2	288	18	6.2
0.0294	310	298	96.2	280	10	3.6
0.0504	243	240	98.8	219	22	10.0
0.1075	462	447	96.8	445	11	2.6
0.1580	251	237	94.5	234	7	3.0

b. Parent fishes were put in a current of intensity: pot.-drop per 1 cm = 0.0739 volts.

Duration of electric action	Number of eggs	No. of hatched eggs	Hatch-rate	Number of fry	No. of ab-normal fry	Rate of abnormity
0 hours	325	297	91.5%	297	10	3.4%
2	184	178	96.8	176	5	2.8
3	298	293	98.4	7	0	0.0
4	237	232	97.5	231	0	0.0
5	282	276	97.9	275	3	1.2

(specific conductivity of water = 5.6×10^{-5}cm ohm^{-1})

In closing this paper the author's sincerest thanks are due to Dr. M. Tauti for his constant guidance and to Mr. M. Kawajiri, by whose courtesy many

conveniences in the Kizaki Fish-cultural Experiment Station were placed at the author's disposal, and also to whom the author owes the performanc of the greater part of the experiment in § 2.

Summary.

1.. Too strong current must not be used when we employ electric current to lead the movement of fish-groups as well as to stop them.

2. The intensity of the current, most adequate to lead groups of *Salmo irideus* Gibbons is found to be about twice as high as that sufficient to be felt by the majority of the fishes.

3. To increase the range of the field of electric current is very effective to stop fish-groups. This stands in good harmony with Dr. M. Tauti's rule previously announced.

4. Electric action on parent fishes, *Leusiscus hakuensis* Günther, has no injuriou sinfluence on the hatch-rate of the eggs, nor on the rate of raising abnormal fry.

October, 1928.

Physical Laboratory,
Imp. Fish. Institute.

*A CONTRIBUTION TO THE KNOWLEDGE OF THE DEVELOPMENT OF *OSTREA DENSELAMELLOSA* LISCHKE.

By

Hidemi Senô.

Besides the most common edible oyster *Ostrea gigas* Thunberg, there are some other edible species in Japan. One of them was first noticed in a faunistic way by Lischke, (Japanische Meeresconchilien. 1869, p. 177) who described it as a new species *Ostrea denselamellosa*, closely allied to the common European oyster (*Ostrea edulis* L.) in the characters of the shell and in being hermaphroditic. But its embryology and larval stages have remained unknown.

The present paper deals with the oösperm, the embryo and all the young shell-bearing stages of the species in question, and some suggestions for propagations are made.

The observations were made during the summers of 1927 and 1928, at our branch station for oyster culture at Futami, near Kôbe. For the kind assistance rendered by Messrs. H. Seki and K. Tanaka, I take this opportunity of returning my warmest thanks.

HERMAPHRODITISM

Ostrea denselamellosa is bisexual, hermaphroditic, or monoecious. The ripe eggs are not discharged into the water, as in many dioecious bivalves, but retained in the branchial cavity, between the two folds of the mantle, where the development is gone through up to the young shell-bearing stages capable of locomotion.

Fertilization takes place in the branchial cavity and cleavage commences immediately after the eggs are discharged from the ovary. The spermatozoa must be introduced with the respiratory current, from other individuals. Attempts for artificial fertilization has so far failed in this species.

THE BREEDING SEASON

The breeding season of *Ostrea denselamellosa* begins in the Seto Inland Sea in the first part of June and lasts until the middle of September, spawning going on most actively from the end of June to the middle of July, when the water temperature is 21°–23°C. It is probable that the breeding season varies

* Paper presented before the Fourth Pacific Science Congress at Batavia-Bandoeng, Java.

with temperature in different places and years.

REPRODUCTIVE CELLS

EGGS.—The eggs are white and spherical, with a large nucleus, and somewhat opaque on account of plenty of yolk. The diameter is almost invariably 105 μ, quite the same as in the common European and American Olympia oyster (*Ostrea lurida*.) Normally the eggs seem to ripen at the same time and they are all extruded in one act.

SPERMATOZOA—The sperm cells of this species are quite different in shape and size from those of dioecious species. The sperm cells newly drawn out from the gonoducts and on the way to become spermatozoa are easy to observe as opaque, elliptical or nearly spherical bodies called sperm-balls or sperm-morulae by Hoek (1883). They execute rolling motions, like some infusoria, by the vibration of the tails of the ripe spermatozoa on the surface, and are of various sizes, being 20-80μ or more in diameter. These balls are aggregations of mature spermatozoa, and if a drop of sea water is added the motion becomes more and more active, and finally become segregated from each other.

SEGMENTATION

All developmental stages, from the unsegmented ova to the fully formed shell-bearing larvae; may be found in the mantle cavity of the parent oyster. But in most cases, the 8-16 celled or later stages are most numerous and fertilized unsegmented eggs are very rare. Although a good account of the development of the common European oyster was given by Horst (1883), the first four drawings in his paper of 1-4 cell stages, are reproductions from Möbius and he added, "And for this reason likewise the first stages of the segmentation of the egg have to a great extent remained unknown to me."

I had the good fortune of finding out some fertilised unsegmented eggs in the mantle cavity of our oyster in June of 1927, and photographs were taken from the extrusion of the first polar body to the 8-cell stage and still later. After giving out the two polar bodies, the egg divides into two unequal spheres, a micromere and a macromere. (Plate III, fig. 5. In the second cleavage, the egg appears very energetic and there results the 4 cell stage, with three micromeres and a large macromere.

The third cleavage affects all the micromeres and a small cell is budded off from the macromere, so that there are now eight blastomeres.

From the fourth cleavage on, it becomes difficult to count all the blastomeres, but the morula stage is now reached. The sixth cleavage leads to the blastula, which is spherical and has a shallow invagination at one pole.

GASTRULATION

At the next cleavage, the blastopore is well developed and the invagination is distinct. Small cells now form a single layer on the surface and constitute the ectoderm, which surrounds the larger cells forming the endoderm, leaving a cleavage cavity between. It is now a typical gastrula, of a somewhat long heart-shape, ciliated, and beginning to swim in a characteristic way. The embryonic period is now at an end.

LARVAL OR SWIMMING STAGES

Shortly afterwards the invagination becomes deeper and constricted at the mouth, the in-tucked ectoderm becoming the epithelial lining of the mouth and oesophagus. The archenteron becomes the mesenteron or stomach and intestine. The intestine is formed as a funnel-like backward outgrowth of the stomach and meets the ectoderm at the posterior edge to form the anus.

The next notable event is the formation of the shell. At first each valve appears as a small glistening spot near the dorsal surface of the soft larval body ; it grows larger, covers more and more the dody, and becomes connected with its mate of the opposite side along the hinge-line ; both valves then extend downwards until they enclose the whole body of the larva except the velum. The shell now measures .15 mm. in length and .14 mm. in depth, with an almost straight hinge line. I will call this the straight-hinge larva. It now leaves the branchial cavity of the parent and takes to pelagic life.

The free-swimming larva grows on and reaches the umbo-stage by the formation of the umbones. Oyster larvae of various stages occur in the plankton together with many other numerous organisms. For the inexperienced students, the identification of oyster larvae is difficult, but the association of certain characters, such as colour, shape, length and depth etc., will enable one after a little experience to recognize them. From the egg to the stage of ciliated heart-shaped larva and the early shell-bearing stage, the colour is white, but owing to the development of pigment at several points of the body, the colour becomes more and more gray or bluish. The shell now measures .23 mm. in length .20 mm. in height.

The gray larva becomes successively pinkish gray, purplish black and quite good black. Small teeth are now present at either end of the hinge. There is a distinct difference between our species and the common European oyster in the distribution of the black pigment. When I was at the Marine Biological Station of Arcachon, France in 1914, I noted that the mouth and oesophagus of the larva of the European oyster was very easy to observe, owing to the great quantity of black pigment, but in our species those parts of the body are wholly free of pigment, so that it is very difficult to locate those organs.

In later stages the thickness of the body from umbo to umbo increases, and the left valve becomes larger and more convex than the right. When the larva is lying on its right side, the smaller right valve is more completely covered over by the larger left.

Afterward, the height of the shell becomes greater than the length, and with further growth, the definitive shape of the grown larva ready to become attached to some solid object is assumed.

The length of the shell now ranges from 370 μ to 380 μ. Once, I suceeded in obtaining the spat on a glass slide in a rearing glass cylinder from full-grown larvae collected in a plankton net.

The following measurements show the length and height of the shell for the various stages indicated:—

No.	Length (μ)	Height (μ)	Stage
1.	148	126	Straight hinge larva.
2.	235	198	,, ,, ,,
3.	280	251	Umbo-stage larva.
4.	295	251	,, ,, ,,
5.	325	248	,, ,, ,,
6.	325	370	Full-grown larva.
7.	347	370	,, ,, ,,
8.	372	382	,, ,, ,,
9.	403	387	Attached to a glass slide.

The larva represented in Fig. 16 is the most advanced free-swimming larva I have observed, and was found in the bottom plankton. Stafford gives approximate measurements of three stages of the European and American oysters as follows.:—

	Egg	Larva (Set free)	Spat (at fixation)
European (Monoecious)	0.1 mm.	0.18 mm.	0.25 mm.

American (Dioecious)	0.05 mm.	all stages free	0.33 mm.

I will add approximate measurements of three stages of two commonest edible species of Japan

	Egg	Larva (Set free)	Spat (at fixation)
Ostrea denselamellosa (monoecious)	0.1 mm.	0.15 mm.	0.38 mm.
Ostrea gigas (Dioecious)	0.05 ,,	all stages free	0.28 ,,

The monoecious *denselamellosa* has eggs of the same diameter as the European oyster, but the length of the spat fixation agrees with that of the American oyster. It is worth further investigation.

SOME SUGGESTIONS FOR PROPAGATION.

Near the Futami oyster bed, spawning seems to be at its height from the end of June to the middle of July, when the water temperature is 21°—23° C.

Careful daily examination of the plankton of the oyster bed during summer, has brought to light certain sequence in the appearance of the swimming larvae. Early in the season straight-hinge larvae were most abundant, afterwards those of the umbo-stage and lastly full grown ones. When the shell is 370-380 μ and the foot is completely developed, the larva begins to attach itself to solid objects.

In the Futami oyster bed, the period of the greatest abundance of full-grown larvae seems to be from the end of July to the first part of August. Fixation takes place about four weeks after spawing, at the water temperature of 20° C. more or less.

Closer observation shows that straight-hinge larvae occur in the upper layer and umbo-stage and full grown ones in the lower layer. It goes without saying that the best time for collecting spat is when full-grown larvae are most abundant. If suitable collectors, such as dead shells, stones, gravel, tiles, etc, are thrown in at this time, abundant spatting will be obtained.

SUMMARY.

1. All developemental stages of *Ostrea denselamellosa* from the freshly fertilized egg to the full grown larva has been traced.

2. The eggs develop in the branchial cavity up to the straight-hinge stage capable of locomotion.

3. Artificial fertilization has not succeeded so far.

4. The size of the eggs and the modes of cleavage and gastrulation are quite identical with those of the common European and the American Olympia oyster.

5. The older free swimming larvae has been ascertained.

6. The younger straight hinge larvae are found near the surface, but older and full grown ones generally sink to the bottom.

7. A distinct difference from the common European oyster consists in the absence of black pigment near the oesophagus and mouth in *denselamellosa*.

8. The full grown larva, with the shell-length of 370-380 μ begins to attach itself to shells, stones, etc., just as in the American dioecious oyster, but not as in the common European-oyster.

9. Very young spat of *denselamellosa* has been ascertained for the first time.

10 Full grown larvae are most abundant from the end of July to the first part of August.

11. Fixation of the larva takes place about four weeks after spawning, later than has been supposed.

12. Collectors will be most effective if thrown in when full grown larvae are most abundant, i.e. from the end of July to the early part of August at Futami.

March, 1929

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Explanations of Figures

PLATE III.

Fig. 1. A Sperm-ball. (×280)
Fig. 2. Matured egg. (×200)
Fig. 3. Showing the first polar body. (×200)
Fig. 4. Showing the second polar body. (,,)
Fig. 5. The 1st Cell division (,,)
Fig. 6. The 2nd Cell division. (,,)
Fig. 6. The 2nd ,, ,, (,,)
Fig. 7. The 3rd ,, ,, (,,)
Fig. 8. The 4th ,, ,, (,,)
Fig. 9. Blastula stage (,,)
Fig. 10. Blastula stage (,,)
Fig. 11. Gastrula stage (,,)
Fig. 12. Farly stage shell (,,)
Fig. 13. A larva of straight-hinge stage (,,)
Fig. 14. Umbo-stage larva (×150)
Fig. 15. Full grawn larva (×150)
Fig. 16. Full grawn larva (,,)

PLATE IV.

Fig. 17. 2—3 celled embryo
Fig. 18. Blastula stage
Fig. 19. Gastrula stage
Fig. 20. Straight hinge larva
Fig. 21. Straight hinge larva
Fig. 22. Umbo-stage larva
Fig. 23. Full grown larva
Fig. 24. A spat attached to a glass slide.

Abbreviations used in Figures

a. Anus.
F. Foot.
G. Gill.
Int. Intestine.
l. Liver
L. S. Left valve
l. sh. Larval shell.
M. Mouth.
mm. Edge of mantle.
P. ad. Posterior adductor muscle.
P. S. Pigment spot.
R. S. Right valve
S. sh. Spat shell.
St. Stomach.
V. Velum.

RELATIVE RATE OF REPRODUCTION AS A PHASE OF POPULATION GROWTH OF ORGANISM.

By

Dr. Arata Terao.

In the present paper is given an extension of a mathematical analysis iniated by Dr. M. Tauti on the population growth. My hearty thanks are due to Dr. M. Tauti for kindly handing over his manuscript to me.

The general formula for population growth

$$y=d+\frac{k}{1+e^{a_0+a_1x+a_2x^2+\ldots.a_nx^n}} \tag{1}$$

may be written

$$l_n\left(\frac{k}{y}-1\right)=a_0+a_1x+a_2x^2+\ldots.a_nx^n \tag{2}$$

if we discard d for the sake of convenience.

Putting Δ=increase of individuals during unit time, we have

$$l_n\left(\frac{k}{y+\Delta}-1\right)=a_0+a_1(1+x)+a_2(1+x)^2+\ldots.a_n(1+x)^n \tag{3}$$

Subtracting (2) from (3),

$$l_n\frac{\frac{k}{y+\Delta}-1}{\frac{k}{y}-1}=a_1+a_2(1+2x)+\ldots.a_n\left(1+nx+\frac{n'n-1)}{2!}x^2+\ldots.\right) \tag{4}$$

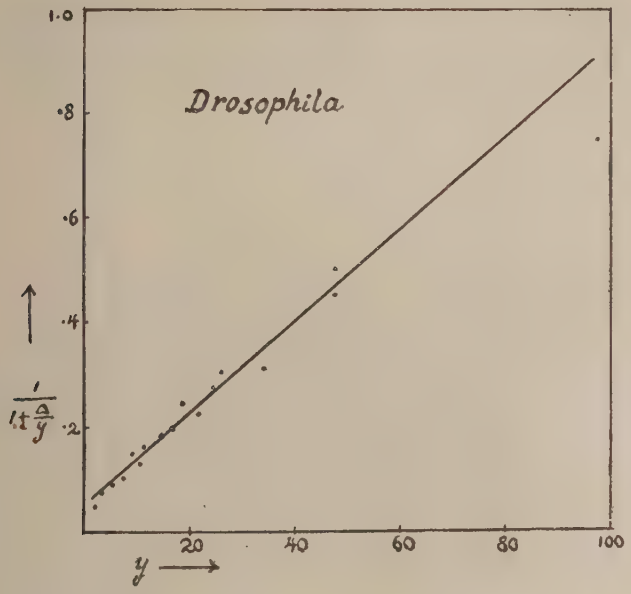
If $a_2=a_3=\ldots.=a_n=0$, we have finally

$$\frac{1}{1+\frac{\Delta}{y}}=e^{a_1}+\frac{1+e^{a_1}}{k}\cdot y \tag{5}$$

Evidently, there is seen in (5) to be a hyperbolic relation between the relative rate of reproduction $\left(\frac{\Delta}{y}\right)$ and the population (y).

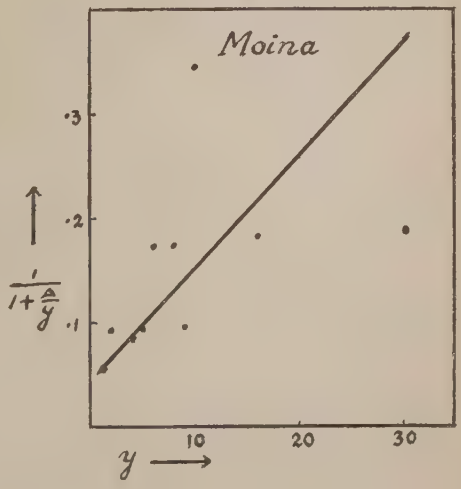
Now, taking the date got from the experiments on the influence of population density upon the rate of reproduction in *Drosophila* and *Moina* as $\frac{\Delta}{y}$ we have such values as plotted in Figs. 1 and 2.

Fig. 1.



It is rather astonishing to find, especially in Fig. 1, that rectilinear relationship is got between the two variables, as should be the case with the data on the population growth. It seems to me, therefore, to point to the fact that there exist some regulating factors which put the two stranis of individual increase to be referrable to the same category.

Fig. 2.



ON THE TEMPERATURE IN RELATION TO THE DEVELOPMENT OF THE GAMETOPHYTE OF *LAMINARIA RELIGIOSA MIYABE*

By

S. Ueda.

The development of some *Laminariaceous* algae has already been made clear by the artificial cultivation of the zoospore by Kylin, Sauvageau etc. In our country such studies have also been done by K. Miyake, J. Ikari and others. Especially Ikari reported the development of *Laminaria religiosa Miyabe* in detail, but the spermatozoid and the union of two sexual elements remained still unknown. I intended to study the temperature in relation to the development of the gametophyte of *Laminaria*. For this purpose I tried to culture the zoospores of *Laminaria religiosa Miyabe* at different degrees of temperature by using the Seno-Tauti's serial incubator.(1) I put a culture-glass in each compartment of the incubator, the temperature of which was maintained at about 24.8°C, 20.5°C, 16.7°C, 12.4°C, 11.3°C, 9.1°C, 6.5°C and 1.9°C respectively, and observed the development almost every day.

1. **The course of the development.**

I got the same result as Ikari's(2) culture and I traced exactly the same course in the formation of antheridia as he stated in his treatise2). I saw some spermatozoids escaping from an antheridium; they have no stigma and were ca. $4.6 \times 3.5\,\mu$ in size, having a very light yellowish-green colour, so that they may be said almost colourless just as the spermatium of the plant in Florideae. Oosphere may be fertilized within the oogonium or just at the exit when it goes out, but in my case, I think, it may probly be fertilized within the oogonium before they escape out of it, because I observed a 2-celled embryo (young sporophyte) at the exit of an oogonium, just escaping from it. But I regret that I was not able to see the critical phenomenon.

2. **On the tempterature in relation to the development of the gametophyte.**

The zoospores cultured at 24.8°C settled in a few hours, but died 2 days

(1) Seno, H. and Tauti, M.: Apparatus for maintaining a series of constant themperature. (Journ. Imp. Fish. Inst. vol. 20, no. 4, 1925)

(2) Ikari, J.: Development of *Laminaria religiosa Miybe*. (The Botanical magazine vol. xxxv, no. 419. 1921.)

later; at 20.5°C some of them began to die on the 3rd day and none of them remained alive on the 45th day; at 16.7°C they grew and formed 3-4 celled monosiphonous plantlets on about the 26th day, at that time, however, some of them ceased to grow and great many of them gradually began to die, and the survivors took abnormal form and finally died about 65 days after the start. At 12.4°C embryospores grew normally and assumed matured forms of gametophyte, but they died before they could form an oospore. Embryospores cultured at 11.3°C, 9.1°C and 6.5°C completed their germination and growth. At 1.9°C the zoospores continued their motion for 3 days and changed to embryospores, they grew very slowly and matured in about 150 days after, but I could not find a sporophyte among them. At 11.3°C young sporophytes were observed to come out from the fronds of the gametophytes after the lapse of about 90 days; at 9.1°C they were observed in about 100-110 day-old culture, and at 6.5°C in 140 day-old. In the cultures at 9.1°C and 6.5°C a large number of sporophytes were observed but a few of them at 11.3°C. Therefore the optimum temperature for the development of the gametophyte may be about 9-6°C. The temperature-coefficient of the development can be calculated according to Arrhenius's equation $Q_{10}=\left(\frac{T_2}{T_1}\right)^{\frac{10}{\theta_1-\theta_2}}$ and I obtained the value $Q_{10}=2-3$. So I think I am justified in regarding the process of the development as a chemical change, not to mention that the higher the temperature is, the faster they develope.

ON THE LIFE-HISTORY OF *PORPHYRA TENERA KJELLM.*

By

S. Ueda.

The economically most important marine alga of Japan, *Porphyra tenera Kjellm.*, has been cultivated in bays and inlets for some three hundred years. Our knowledge of its life-history is, however, very meagre. Therefore, at the suggestion of Dr. K. Okamura who has paid special attention to its life-history for may years, I undertook the present study. I am much indebted to Dr. K. Okamura for his kind supervision. To Drs. K. Miyake and M. Tauti I am obliged for valuable suggestions. My hearty thanks are also due to Mr. D. Kusakabe for his kind coöperation.

This alga is one of the so-called "annual marine algae" and appears only in a certain season of the year. The sporelings of this alga come out about the end of October and are found attached on the twigs of dead trees or bamboo, which are planted in shallow water for the culture of the alga. The sporelings grow up to mature plants during the winter and at last form the carpospores after the union of sexual cells. In the spring of the next year the plants begin to die, being gradually swept away from the twigs and sooner or later disappear entirely. The fate of the carpospores after their liberation, however, has been unknown, since the carpospooes do not germinate easily under the laboratory conditions. Some algologists suggested in this connexion that they may remain in the resting condition during summer and germinate in autumn.

In October 1926, numerous spores of *Porphyra* were first found by Mr. Kusakabe suspended in the water of an inlet where the alga is cultivated. But the spores were, according to my own observation, somewhat different from the carpospores of the winter plants, the former being somewhat greater in size and having much thicker cell-wall. The chromatophore of the former is fainter in color and has an arachnoidal form whereas that of the latter is darker in color and fills up the entire cell.

It was found in November 1926, that some marginal cells in a very young frond of *Porphyra* (about 3-4 mm. in size) growing on twig had swollen up to assume spore-like appearance and finally detached from the frond. These (round) cells were almost identical with the above mentioned light colored spores in every respect. These cells are monospores as first suggested by Dr. Okamura and later proved by Mr. Kusakabe's culture-experiment. Mr. Kusakabe orally informed me that the cells in question had germinated and grown to the *Porphyra* plantlets just as Dr. Okamura anticipated. Consequently the spores which were found suspended in water in October may also be monospores.

By the way, I made some observations on other algae, *Enteromorpha sp*, *Ulva sp*, *Monostroma sp*, etc., all of which grow almost in the same period and in the same places as *Porphyra*. At the result of these observations I could ascertain that these algae are growing even in summer, but it is not so easy to find them out because of their insignificant shape and habitat.

It may be mentioned that 1) the carpospores could occasionally germinate in laboratory, 2) some carpospores were found germinating in their mother fronds, 3) very small fronds of *Porphyra*, probably just grown up from the

newly liberated carpospores, were frequently found growing on the twigs in spring, 4) the carpospore has very thin cell-wall and is very weak, not fitted to become resting spore, 5) the carpospore was not found in the water or in the bottom-soil during summer, 6) the spores found suspended in water in October 1926, were nothing but monospores. So, I had expected that the carpospores of *Porphyra* would germinate, in nature, after their liberation and grow to fronds wherever the conditions are favourable for their growth.

On 17 th of July in 1927, I went to Kanazawa where *Porphyra* is cultivated for many years, and tried to search the plant which was supposed to have generated from the carpospore. I could succeed in finding out very small and light colored plantlets which were decidedly referrable to a species of *Porphyra;* they were growing on rocks, stones and woody works in the littoral and sublittoral zones. But it was not certain whether these Plants were generated from the carpospores of *P. tenera* or from those of other species of the same genus. If these plants growing in summer are generated from the carpospores in question, they must produce spores in autumn. Thereupon I cultured them at a lower temperature according to Dr. Tauti's advice. In this culture, when the plants were kept at 15.5°C, some marginal cells of the fronds changed after 24 hours to monospores which were just like the spores suspended in water in October 1926. These monospores germinated soon after liberation from the frond and grew up to the plantlets. Then I started an experiment to ascertain at what temp. the monospore is formed. Accordingly, I cultured the plants at different degrees of temperature by using the Seno-Tauti's serial incubator,* I put a culture-glass in each compartment of the incubator, the temperature of which was maintained about 6.8°C, 10.9°C, 14.5°C, 17.4°C, 20.5°C, 23.1°C, 26.1°C, 29°C, 31.8°C and 34.9°C respectively. At temperatures 17.4°C and 20.5°C the plants produced many monospores, but they did not otherwise form one. The plants cultured at temp. lower than 14.5°C or higher than 29°C began to be damaged and finally died. Such experiment was repeated by Mr. Kusakabe and he got almost the same result as mine.

The temperature of the sea-water in autumn when the sporelings appear, is about 17°C–20°C. Therefore I think that the plant growing in summer produces monospores in autumn when the temperature of sea water goes down,

* Seno, H. and Tauti, M.: Apparatus for maintaing a series of constant temperature. (Journ. Imp. Fish, Inst. vol. 20, no. 4, 1925).

and thus *Ponphyra* propagate themselves by these monospores.

As regards the fate of the carpospores in question, it may not be far from the truth to say that the carpospore germinate soon after the liberation and grow up to a plantlet which is different in size, form and color from the mother plant growing in winter, and passes summer time as it is, and in autumn, the ordinary vegetative cells of the plantlet change to monospores to liberate from the frond which is likely to decay thereafter. These monospores probably give rise to fronds of *Porphyra* in winter.

March, 1929. Botanical laboratory
Imp. Fish, Inst. Japan.

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